Variation of ^{40}K, ^{238}U and ^{232}Th specific activities in soil within geological units of Republic of Macedonia

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Introduction

Radionuclides have been an essential constituent of the Earth since its creation. The natural occurring radionuclides of primary importance are ^{40}K, and the radioactive decay chains of ^{238}U and ^{232}Th . The concentrations of these radionuclides in soil and rocks is closely related to geology.

Territory of Republic of Macedonia is situated on area of 25.713 km^2. According to geology, is roughly divisible in four geotectonic zones and one separate volcanic area: Kratovsko-Zletovska Area (KZA) (Figure 1).

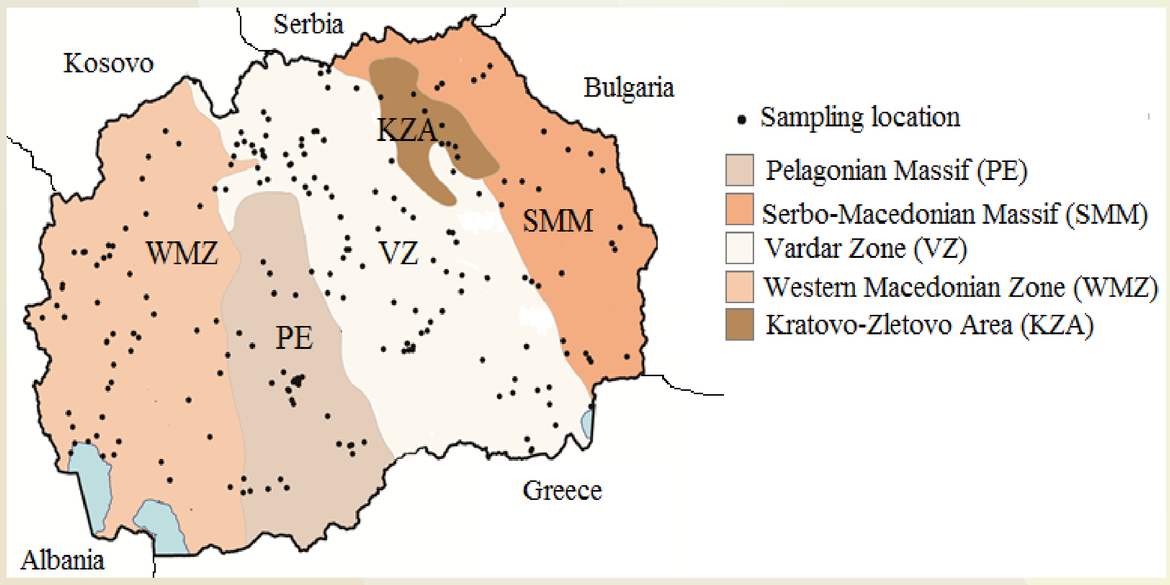

Figure 1 Spatial distribution of sampling locations over five geotectonical unints of the Republic of Macedonia

In order to produce representative data for the country natural background, a field campaign was conducted for top soil radioactivity assessment. In this paper, we reported the results of the study focusing mainly on the comparison between geologically classified data, to detect significant difference. Results on radioactivity level reported in this study can be included into baseline map of radioactivity background levels in Republic of Macedonia, which will contribute to improve available data worldwide.

Materials and methods

A total number of 213 soil samples from 20 cm depth were collected around the major settlements and cities of the country considering as well all the geotectonic units presented in Figure 1. After their standard preparation, the samples were subjected to high-resolution gamma spectrometry.

The purpose of the gamma spectrometry measurements was to determine the activity of each of the following radionucleides: ^{40}K, ^{232}Th and ^{238}U, The activity of ^{40}K was determined from the 1460 keV line, whereas the activity of ^{232}Th was determined from the gamma lines of ^{228}Ac (338.32 keV, 911.2 keV, 968.97 keV) and ^{208}Tl (583.19 keV) and ^{238}U from the gamma lines of ^{234}Th(63.28 keV) and ^{234m}Pa (1001.03 keV). The analysis procedure included subtraction of the background spectrum, correction for interfering lines and correction for self-absorption.

Results and discussion

Descriptive statistic of ^{40}K, ^{232}Th and ^{238}U specific activities is given in Table 1. Figure 2 shows the histograms of the measured specific activities for each radionuclide separately.

Table 1. Descriptive statistic of measured data

Radionuclide	*A* (Bq/kg)		
	^{40}K	^{232}Th	^{238}U
No. of observations	213	213	213
Minimum	80	7	9
Maximum	1390	145	111
Median	584	39	39
Arithmetic mean	585	41	41
Standard deviation	192	18	17
Geometric mean	550	38	38
Geometric standard deviation	1.47	1.54	1.53

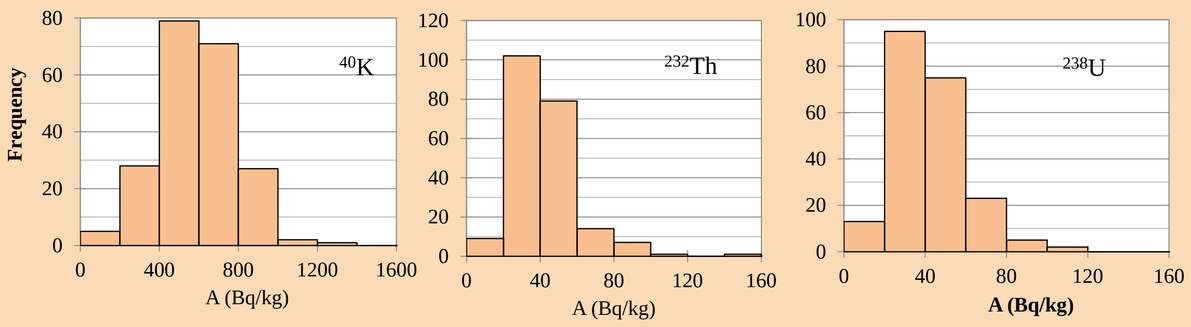

Figure 2: Histograms of ^{40}K, ^{232}Th and ^{238}U specific activities

Radionuclide specific activities variation

The main goal in our data analysis was investigated relationship between geology and measured radionuclides activities. For that purpose we grouped data according to: geological unit, geological era, genetic soil classification and lithology. Geometric mean values of radionuclide specific activities for the groups are given in Figure 2 and Figure 3.

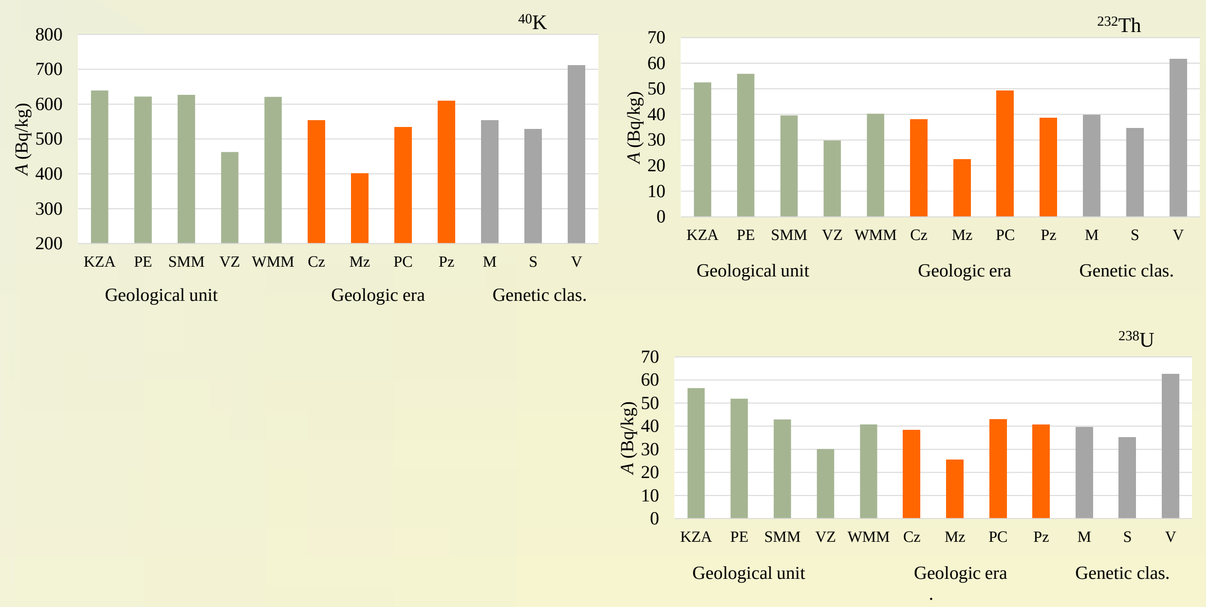

Figure 3. Geometric mean values of ^{40}K, ^{232}Th and ^{238}U specific activities grouped according to geological units, geological era and genetic soil classification. In bricked: pairwise comparison of the results

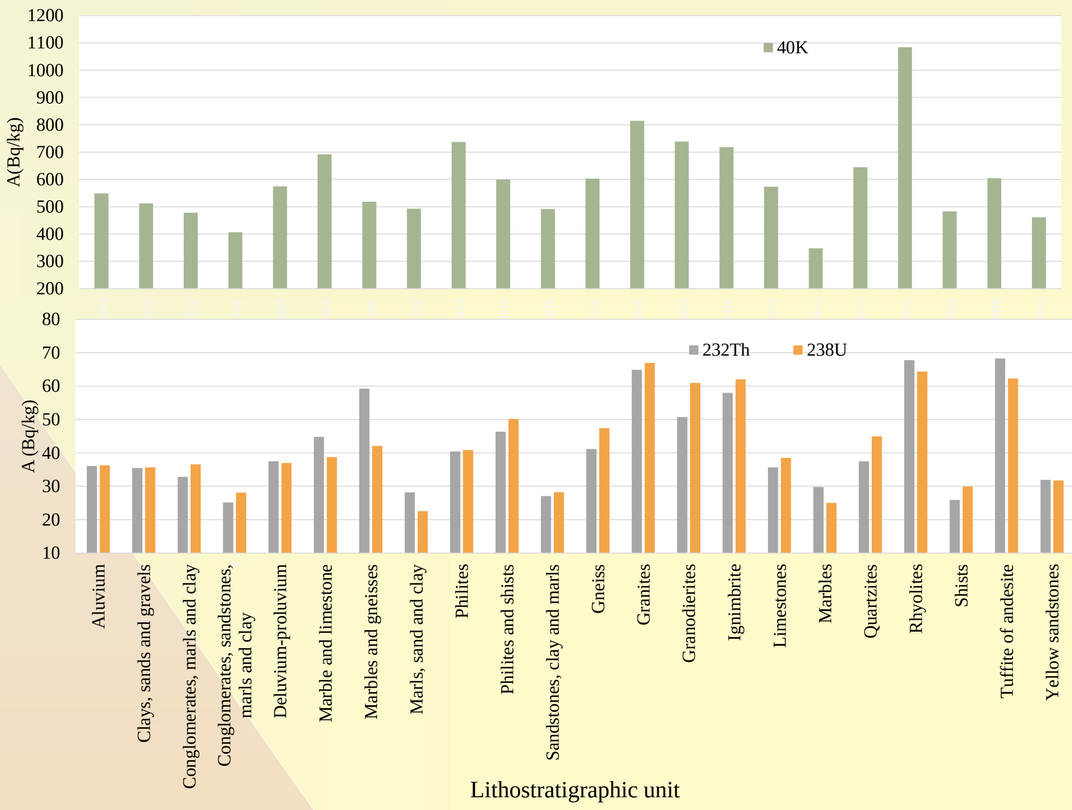

Figure 4. Geometric mean values of ^{40}K, ^{232}Th and ^{238}U specific activities grouped according to lithostratiology

Discussion and conclusion

The world average concentrations are reported by UNSCEAR (2000) as 400 Bq/kg for ^{40}K, 35 for ^{232}Th and 35 Bq/kg for ^{238}U. The geometric mean values given in Table 1 are higher in comparison to world average.

The histograms given in the Figure 2 indicate normal distribution for ^{40}K, while as right tiled shape appeared for ^{232}Th and ^{238}U. The null hypothesis for ^{40}K normal distribution and ^{232}Th and ^{238}U log normal distribution were confirmed statistically at 95% confidence level applying Kolmogorov-Smirnov test.

The results of the analysis of the variance showed statistically significant differences among the specific activities (*A*) of ^{40}K, ^{238}U and ^{232}Th measured from soils of different geotectonic units (Figure 3). For ^{40}K, ^{238}U the values in corresponding geotectonic units are: VZ<KZA,PE,SMM, WMM, while for ^{232}Th there are: VZ<SMM, WMM<PE,KZA. According to geological era, the results for all radionuclides were grouped into two group: whre the loves values are related to the Mezozoic period in comparison to all other: Mz<Cz,PC,Pz. Further analysis confirmed that these differences are related to the type of the rocks from which soils originate, and hence to the geological composition of each lithological area. Pairwise Comparison activity analysis of the three radionuclides, resulted in grouping of the soils into two major groups: the first one to be soils of volcanic origin, and the second one to be soils of metamorphic and sedimentary origin. Furthermore, the soils results were classified by lithostratigraphic units (Figure 4). It also appeared that they show a grouping tendency. According to the differences among *A*(^{40}K), *A*(^{238}U) and *A*(^{232}Th) in the different lithostratigraphic units, the results were grouped into four groups.

Reference

UNSCEAR, 2000. Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effect of Atomic Radiation, United Nations